Adaptive Virtual Enterprise Process Management
Perspective of Cloud-based Data Storage

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Abstract: This paper presents research outcomes on formation and operation management of virtual enterprises (VE). A VE is considered as a temporary alliance of manufacturing companies with the objective to exploit fast-changing business opportunities and to meet demands of globalized markets. In the operational phase of the VE, its collaborative member companies - which are geographically distributed and organizationally independent, cooperate with each other to execute different essential business processes. Keeping this business objective in mind, this paper proposes an integration framework of VE, where necessary data exchange and management among the partner companies are monitored and controlled by the help of cloud-based data repository system. The cloud-based data storage system which provides the necessary data storage and retrieval facilities to execute the VE processes is elaborated within this research scope. A case example is also presented that highlights required interfacing and adaptation of the essential VE business processes with the help from cloud-based data storage and retrieval system.

1 INTRODUCTION

In order to compete with today's turbulent business environment manufacturing companies, especially small and medium enterprises (SMEs) are looking forward to be collaborative, where the possibility of sharing resources and expertise's are quiet high. This business requirement motivates companies to form and operate a Virtual Enterprise (VE), which enables them to fast and reliable adaptations of business processes. Collaborative business environment offers companies to overcome their limited flexibility, real-time monitoring and control over the complete supply chain in terms of buffer level and delivery status, faster partner finding, advanced forecasting of demand level, etc., (Kankaanpää et al. 2010; Carneiro et al., 2010).

VE is the concept where multiple factories form a virtual factory and are integrated by a holistic ICT platform, leveraging with required data transfer and information flow among them. This collaboration offers interoperability among the partner factories at a deeper technical level and ensures that the factories can be technically connected with each other (Park and Favrel, 1999). The VE works on the principle of plug and play, where on-the-fly collaborative environment is established. In the plug phase of the VE, factories provide information which is semantically enriched descriptions of manufacturing capabilities offered by them, which are exposed as services (Shamsuzzoha and Helo, 2012). On the other hand, in the play phase, factories are provided with semantically enriched descriptions of required manufacturing capabilities and process models as composition of services. The VE framework provides methodologies to register new factories in a joint registry and allows manufacturers to find factories which meet the demands of a given set of capabilities. This matchmaking process is performed by comparing the semantic descriptions and by taking into account various selection criteria such as price, quality or speed. This approach allows manufacturers to define a distributed manufacturing process and to distribute the different steps of the process to different factories.

In order to establish a successful VE, collaborative factories need to develop a data storage and retrieval system that control and monitor the overall process execution. This data storage and retrieval system needs to be efficient so that offers enhanced agility. Today's widely accepted cloud services could be an answer for such purpose, where

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factories could reduce their reliance on an internal IT function and to make sure they get a satisfactory level of service from cloud providers. Cloud-based data storage refers as central data storage that allows storing different types of data (binary, semi-structured, semantic) and ensures high scalability for data storage processes. It essentially provides functionality to store different predefined and not predefined semi-structured data like company profiles, service descriptions, relationships, monitoring data, processes etc., semantic data like service descriptions and binary data like documents or images.

2 THEORETICAL FRAMEWORK

Nowadays, growing trends within business supply chains for the production of complex products in collaboration with a number of autonomous organizations. This collaboration can be in the form of VE that provides functionality which goes significantly beyond traditional approaches for inter-organizational workflow management (Grefen et al., 2009). Such collaboration contributes to added agility, visibility and effectiveness among partner organizations by creating and operating an automated cooperative support for design, set up and enactment of required business processes within the VE (Camarinha-Matos et al., 2008; Shamsuzzoha et al., 2010). The concept of VE is not only to cooperate within the distributed and heterogeneous business environment only but to ensure a proper management of dependencies between activities within the partners is in place (Kaihara and Fujii, 2008). Within this business environment, there needs to store and retrieve huge amount of data which demands for reliable and secure data storage facility. The advancement of cloud technology can provide such facility within the reduced budget and expected security protocol.

The concept of cloud computing refers to the delivery of both computing and storage capacity to a heterogeneous community of end users. It resembles services with a user's data, software and computation over a network (Marston et al., 2011). There are three types of cloud computing are generally available such as Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). In the IaaS, users rent use of servers according to needs as provided by the cloud providers, whereas, in the PaaS, users rent use of servers over which the software systems are implemented. In the SaaS, the users also rent different application software and databases according to their needs. The cloud provider maintains and manages the infrastructure and platforms over which the specified applications are run (Furht, 2010; Rimal et al., 2011; Sakr et al., 2011).

In a collaborative business environment, cloud services provide ample opportunity to the business partners through managing the valuable real time information exchange (Wang et al., 2009; Grossman et al., 2009; Narasimhamurthy et al., 2012). Different cloud services such as cloud computing and data storage facility provide partners to know the status update through process monitoring and risk and event management. It allows partners to concentrate on the core business aspects without having to care about the technical management of the cloud infrastructure and with benefiting from elastic cloud facilities and flexible pricing models.

It also facilitates to message transfer among various VE processes such as forecasting and simulation, adaptation and execution, and designing a process from a scratch by providing pre-stored template. Information exchange among the collaborative partners through the cloud storage provides various supports to the VE networks such as discovery of potential new partners, react quickly to late changes, manage rush orders, real-time buffer status, improve business interactions with the customers, etc.

3 VE PROCESS MANAGEMENT THROUGH CLOUD-BASED DATA STORAGE

The process management is the prime task to control and maintain the VE with its target goals. Member companies within the VE are increasingly interested in better organized their business processes and optimizing them. The fundamental concern for the partner companies is to find a way to deploy new process management platform that lower costs with enhanced overall process visibility. Every collaboration network operates through the effective implementation of a wide range of processes that enable its members to perform their roles within the business. The volume and complexity of these processes grows exponentially as the business grows. The objective to process management is to design and efficiently organize the companies various processes by promoting effectiveness, improve management, reduce costs, improve quality and customer service.

Enabling VE process management over the cloud is a concept that organizations are embracing and this service is growing in popularity among different manufacturing companies that have yet to transition IT operations over to the cloud (Mvelase et al., 2011). In the recent years, there has been an extended interest about cloud computing, which is on the top of Gartner's list of the ten most disruptive technologies of the next years (Gartner, 2008). Cloud computing offers the new paradigm for the provision of computing infrastructure that reduce the costs associated with the management of hardware and software resources (Sakr et al., 2011). Different cloud service providers such as Amazon, Google, Face book and Salesforce.com, IBM, Microsoft and Sun Microsystems have embrace this type of infrastructure and make their applications availability through web browser in various locations around the world to provide redundancy and ensure reliability in case of site failures.

Due to the requirement for providing scalable database services many existing applications are extended towards the cloud platform. This platform uses cloud computing as one of the primary sources for data storage. The data stored within the cloud in a particular place with a specific name although that place does not exist in reality. It is just a pseudonym used to reference virtual space carved out of the cloud (Wu et al., 2010).

The processes as related with the VE operation are defined and stored within the cloud storage. All the relevant information associated with a process such as process template, process model, process editor, process design, etc., is stored and retrieved from the cloud storage as necessary. This functionality from the cloud storage provides extra benefits towards managing the processes from the user side to the data management side. Typical virtual enterprise interface between the client side and the cloud storage side can be presented as displayed in Fig. 1. From Fig. 1, it is seen that level of VE interfaces starts from the user interface layer followed by data exchange layer and process management layer, which all access and exchange data by using the cloud storage layer.

The user interface layer usually contains elements such as dashboards, process designers and management/admin components. The data exchange layer usually contains components for message transfer but also for message transformation, e.g. syntactically mapping XML to JSON formats or even by semantically mapping one XML standard to another. Based on this, the process management layer contains components of the VE for executing processes and managing the information flow of the VE. This contains components for monitoring, forecasting and process adaptation.

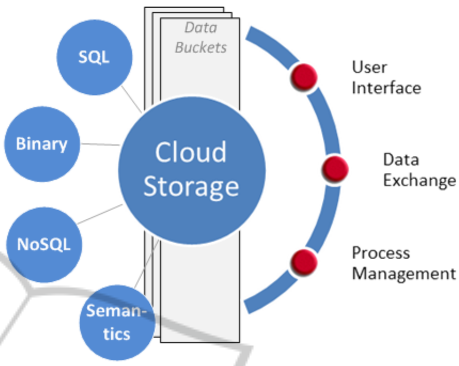

Figure 1: Cloud Storage structure within VE environment.

Finally, the cloud storage layer, as displayed in Fig. 1, may consist of different storage back ends such as SQL for structured data or Binary back ends for e.g. images or enterprise specific files. This aspect will be further discussed in the following section, introducing the concept of so called "data buckets".

4 CLOUD-BASED DATA REPOSITORY

As mentioned earlier cloud-based data repository implement as an intrinsic part of the cloud computing, where data is stored on multiple third-party servers, rather than traditional networked database. The architecture of the cloud storage is built in a way that it allows the usage of different storage types. The reason is that VEs may need to store different data in the cloud reaching from binary information via structured information to semantic information. Each of those data types is usually stored in different systems. For example, there are many traditional hosted or managed service providers (MSP) offering block or file storage, usually alongside traditional remote access protocols or virtual or physical server hosting (Wu et al., 2010). Additional storage technologies exist to manage the data types such as structured data (e.g. offered by the Google Base storage).

Since the Cloud Storage has to store data from several components, all data will be stored in so called "data buckets". A bucket is a data storage space which is fully isolated from other spaces and may be used by a component to store its data. One component may use several different data buckets and may specify their access level (private, publically writable, publically readable) for sharing buckets with other components. Each bucket has a "bucket type", which specifies the nature of the storage space, e.g. "binary data storage" or "semantic data storage".

The cloud storage is maintained dynamically, where its storage location can be varied from time to time. The services as cloud storage offer are typically cheaper than dedicated physical resources connected to a personal computer or network. It provides data security from accidental erasure or hardware crashes, due to it is duplicated across multiple machines and even if one machine crashes, the data is copied on other machines in the cloud. Generic cloud storage repository follows the methodology as presented in Fig. 2.

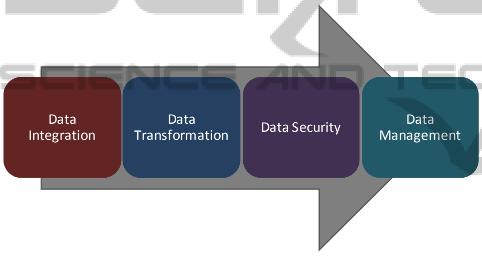

Figure 2: Methodology for a typical cloud-based data repository.

From Fig. 2, it is noticed that cloud storage follows the methodology data integration, data transformation, data security and data management. The data integration stage offers the ability to integrate data across and outside of the enterprise, as well as electronically connect with business partners, whereas, in the data transformation level, the data as exchanged between the partners are made compatible even it was not initially. This data transformation and data mapping solutions helps companies to coordinate and streaming the translation of information between systems. In the data security stage, cloud-based data repository offers solutions to handle business data encryption, tokenization and key management and secure file transfer needs. At the final stage, based on a scalable platform data management solutions help companies to transform master data into accurate, consistent and relevant information.

A typical architecture for cloud-based data repository consists of a cloud provider that works as a master control and several implementation servers as shown in Fig. 3. Potential customers directly

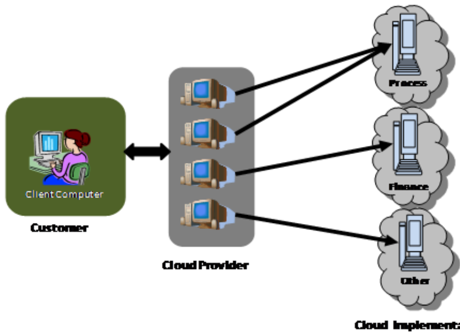

Figure 3: Typical cloud-based data repository system architecture.

interact with the third-party cloud providers and indirectly interact with the implementation services as displayed in Fig. 3. Customers access to cloud to store and retrieve required data or information through the cloud provider instead of storing data or information to their own hard drives or other local storage devices. Instead of local device the data is saved to a remote database which is connected by Internet between the client computer and the cloud databases through cloud provider. This approach advocates collaborative effort to get the data from any location that has the Internet access.

5 CASE EXAMPLE FOR A VE NETWORK

The prime task of process management layer is to control and maintain the activities as needed to execute the virtual enterprise successfully. This is done by integrating various business processes within the VE and is applied over a web-based platform named as 'Liferay' (www.liferay.com). This platform works as a dashboard user interface, from where users (broker and partners) can monitor and manage the entire VE network successfully. It provides real-time control over the collaborative network. This communication framework is proposed within the ADVENTURE European Commission project (Ref: 285220) (ADVENTURE, 2011), which will be updated eventually. This framework consists of four layers such as Process Design, Process Management, Partner Management and Application Management as depicted in Fig. 4.

Each of the layers of this example VE contains different sub layers. For instance, Process Design layer consists of Process Model Template, Process Designer, Simulation and Optimization sub-layers, whereas, in the Process Management layer contains Instance Management and Alerts. The Partner

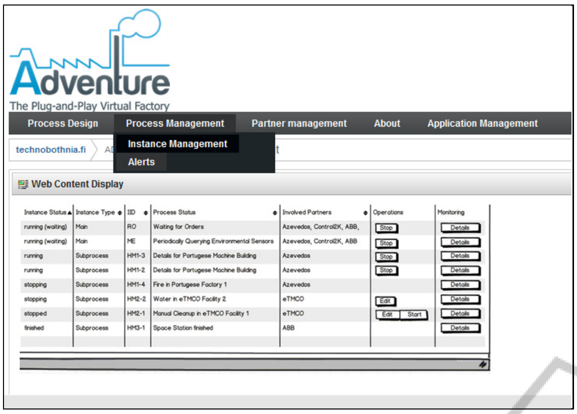

Figure 4: VE processes monitoring and management framework.

Management layer consists of Profile Editor, Partner Search and Partner Analysis sub-layers. Fig. 5 displays an example screen shot of Partner Management layer and its associated sub-layers within the VE network.

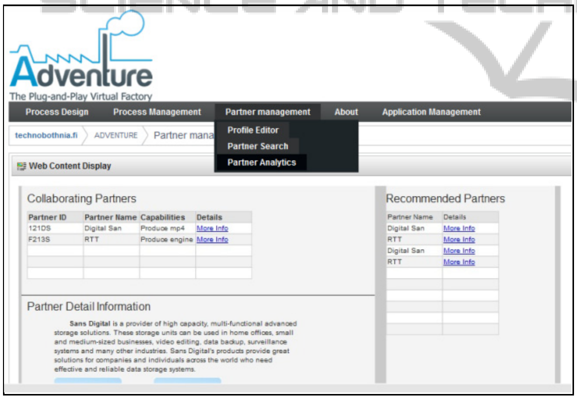

Figure 5: VE partner finding and profile management framework.

The Application Management layer of the VE as shown in Fig. 6 is responsible for User Management, Dashboard Configuration, Gateway Configuration and Alarms Configuration. All the valuable information as necessary to execute a successful VE framework is stored within the cloud-based data storage system, from where; VE users/partners would be able to retrieve necessary data/information. The cloud-based data storage for the ADVENTURE platform is based on highly virtualized, distributed infrastructure and has the characteristics such as agility, scalability, elasticity and multi-tenancy.

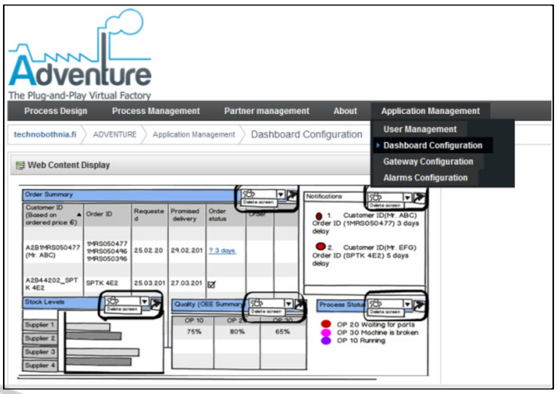

Figure 6: VE configuration management framework.

6 DISCUSSIONS AND CONCLUSIONS

Collaborative operational processes are the prime concerns in today's business arena, where manufacturing companies are motivated to share resources, competences and processes in order to be benefited mutually (Chen et al., 2010; Lee et al., 2012). This motivation influences them to form and operate a VE immediately after identifying any particular business opportunity. VE achieves its objective by defining and implementing processes that are distributed across several organizations. This means that the processes must be coordinated and synchronized at a global level, where VE implementation needs to integrate resources, organizational models and process models of the participating companies.

To enable partners to adapt to this new business environment, extensive communication framework is needed which provides necessary data exchange and flexible integration between partners in the value chain. Data exchange platform is considered as the foundation for collaborative business network. The essential data exchange and data storage facility can be provided through the cloud infrastructure, where the main goal is for deploying data-intensive computing application in cloud environments. The cloud environment provides availability, scalability, elasticity, performance, multi-tenancy, load and tenant balancing, fault tolerance, ability to run in a heterogeneous environment and flexible query interface (Sakr et al., 2011).

This cloud-based data storage system within the cloud environment provides necessary support for all message formats and standards, transfer protocols and processes as needed to execute a virtual enterprise. Various hands on knowledge and experience as achieved by running a VE can be safely stored and retrieved based on their availability and implementation perspectives. The execution of a VE fundamentally depends on the secured database system which can be run within the cloud environment. This research contributed towards the basic integration principle between different VE processes and with the cloud-based data storage system. This implementation process is also highlighted by presenting a case business network, where different collaborative VE processes are created and managed by the cloud-based data repository system.

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